Fig. 20. *Cristellaria cephalotes*, Reuss.
,, 21. *Rhabdogonium insigne*, Reuss. 21*a*, lateral aspect; 21*b*, oral aspect.
,, 22. *Nodosaria* (*Dentalina*) *legumen*, Reuss.
,, 23. *Marginulina debilis*, Berthelin.
,, 24. *Nodosaria* (*Dentalina*) *communis*, d'Orb.
,, 25. *Cristellaria rotulata* (Lamarck). Magnified 33⅓ diameters.
,, 26. *C. gracillissima*, Reuss.
,, 27. *C. gaultina*, Berthelin.

(*To be concluded in the next Number.*)

III.—Some new Rock-building Organisms from the Lower Carboniferous Beds of Westmorland.

By Professor E. J. Garwood, M.A., F.R.S., F.G.S.

(PLATES XX AND XXI.)

In my account of the Lower Carboniferous rocks of the North-West of England, published in 1912, I figured an organism, probably the thallus of a calcareous alga, which plays an important part as a rock-builder at the base of the *Seminula gregaria* sub-zone in Westmorland and Lancashire.[1] More recently, at the meeting of the British Association in Birmingham,[2] I pointed out the need of some distinctive name for this important form, and suggested for it the generic name of 'Ortonella', from the village of Orton, near Tebay, in the neighbourhood of which this fossil is specially abundant. Two other structures were mentioned at the same time which occur constantly in microscopic sections of the Lower Carboniferous rocks of the North-West of England and elsewhere. The first of these was alluded to under the general descriptive term 'festoon structure', and the other was referred to Gürich's somewhat obscure genus *Spongiostroma*. In view of the zonal value of these organisms in the North-Western Province and the probability that they will be found to be widely distributed in the Lower Carboniferous rocks elsewhere, I propose here to give a somewhat fuller description of these forms than could be attempted in the limits of a presidential address.

Ortonella, gen. nov. (Pl. XX, Figs. 1–4.)

Mode of Occurrence.—The remains of this organism occur in the form of sub-spheroidal nodules varying in size from that of a marble to that of a tangerine orange, the largest example met with having a diameter of 5 cm. (Fig. 1). The fractured surfaces of the nodules show a porcellanous texture and a uniform rich brown tint, while a distinct concentric arrangement is usually noticeable. In transparent slices a fibrous structure radiating from the centre can also be observed with a strong hand lens. The smaller examples resemble, in general appearance, the nodules of *Solenopora* which occur in the underlying sub-zone in Westmorland and likewise the nodules of *Mitcheldeania* which are found so abundantly in the Lower Carboniferous deposits of Mitcheldean and North Cumberland.

Under the Microscope.—The thallus is seen to consist of a series of fine ramifying tubes which radiate from the centre of the nodule in every direction. The tubes vary slightly in size, the lumina having on an average a diameter of about 32 μ, and individual tubes show a nearly uniform diameter throughout. The tubes are typically straight or so slightly undulating that in thin slices passing approximately through the centre of the nodule many of these tubes remain in the plane of the section for considerable portions of their length (Fig. 2).

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[1] Q.J.G.S., vol. lxviii, p. 449, pl. xlvii, fig. 2, November, 1912.

[2] Rep. Brit. Assoc. 1913, Section C; also Geol. Mag., Dec. V, Vol. X, pp. 440, 490, 545, 1913.

The tubes are circular in cross-section, completely separated, and often widely spaced. They show marked dichotomous branching (Figs. 3, 4), the angle of divergence of the branches being usually about 40°, and there appears to be a tendency for this branching to take place in several neighbouring tubes at about the same distance from the centre of the nodule. The tubes appear to be completely devoid of transverse partitions, and no trace of perforations has been observed in their walls. They are now filled partly with crystalline calcite and partly with fine dark marly sediment, while the spaces between the tubes are occupied by similar materials. The concentric appearance of the nodules seems to be due partly to the increased proximity of the tubes where bifurcation occurs and partly to the denser character of the matrix, which has remained more completely entangled where the tubes are in closer approximation.

Genotype.—Ortonella furcata, sp. nov. (Pl. XX, Figs. 1–4.) All the examples so far met with in Westmorland belong apparently to one species, which, on account of its marked dichotomous branching, we may appropriately speak of as *Ortonella furcata.*

Horizon.—In the algal layer at the base of the *Seminula gregaria* sub-zone, *Athyris glabristria* zone; Lower Carboniferous, Westmorland and Lancashire.

Localities.—Orton; Ravenstonedale; Shap; Eskrigg Wood, near Summerlands—in Westmorland; and near Low Meathop in Lancashire also, sparingly, at about the same horizon immediately below the Fell Sandstone in North Cumberland and North-West Northumberland. I have also met with a few examples, referable to this species but with somewhat finer tubes, in the *Modiola* beds of Dr. Vaughan's classification near the base of the Lower Carboniferous rocks in the Avon Gorge.

Resemblances and Differences.—In general appearance under the microscope, this organism most closely resembles the genus *Mitcheldeania* described by Mr. Wethered from the Lower Limestone Shales of the Forest of Dean,[1] a fuller account of which was subsequently given by the late Professor Nicholson in 1888,[2] from the Lower Carboniferous rocks of Kershope Foot on the Scottish Border.

Our genus resembles *Mitcheldeania gregaria*, Nich., in the radiating mode of arrangement of its tubes and in the fact that it exhibits dichotomous branching. It differs from it, however, in the smaller size of the tubes, their straight and more uniform character, and their much wider spacing. Again, though both genera exhibit dichotomous branching this takes place much more frequently and

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[1] GEOL. MAG., Dec. III, Vol. III, p. 535, Pl. XIV, Fig. 6, 1886, and Proc. Cotteswold Nat. Club, vol. ix, p. 77, 1886.

[2] GEOL. MAG., Dec. III, Vol. V, pp. 16–19, Figs. 1, 2, 1888.

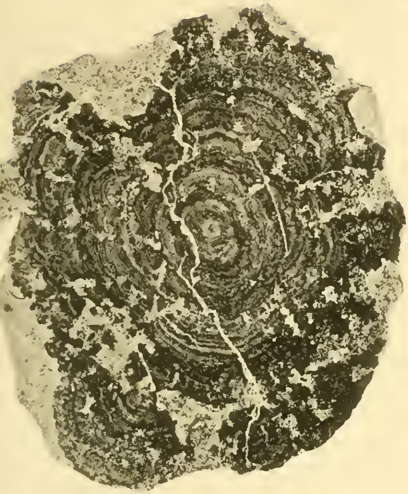

Fig. 1. $\frac{1}{1}$.

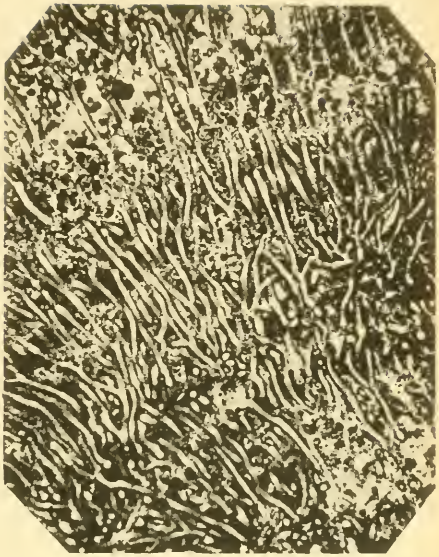

Fig. 2. × 20.

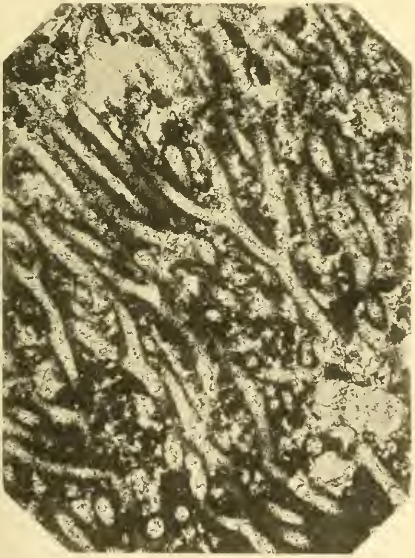

Fig. 3. × 55.

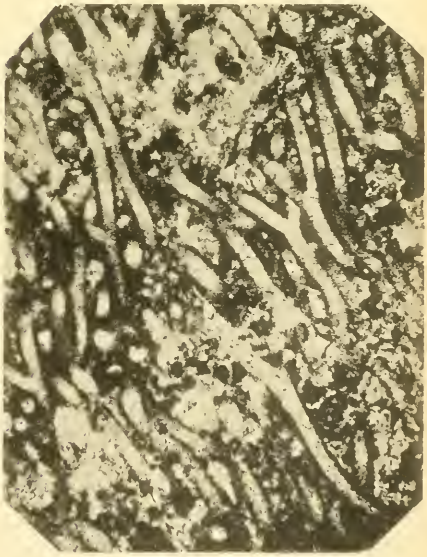

Fig. 4. × 55.

E. J. Garwood, photo. *Bemrose & Sons Ltd., Collo.*

Ortonella furcata.

uniformly in *Ortonella* than in *Mitcheldeania*, while the angle of divergence of the branches is also much greater in *Ortonella*, thus giving rise to the marked difference in the spacing of the tubes in the two genera. It also differs from *Mitcheldeania*, as described by Nicholson, in the absence of cross partitions to the tubes and the imperforate character of the walls, and also in the general absence of the finer series of tubes which Wethered and Nicholson regard as an essential character of *Mitcheldeania* (Pl. XXI, Fig. 2). The structures described by Nicholson as cross partitions in the tubes are, however, very irregular and frequently entirely absent in the Cumberland examples of *M. gregaria*, while the perforations in the cell-walls mentioned by the same author are very obscure, and, as I have already stated,[1] I have been unable to discover any true pores in the Cumberland specimens of *M. gregaria*, even in those which I have collected from Nicholson's type locality at Kershope Foot. It is possible, therefore, that the large pores figured by Nicholson are in reality the elbows of the undulating tubes intersected by the plane of the section.

As regards the finer series of tubes in *Mitcheldeania* (Pl. XXI, Fig. 2), these appear to be typically present in examples of *M. Nicholsoni* and in most of the larger specimens of *M. gregaria*. I have, however, frequently found them to be absent from small examples of *M. gregaria*, the nodules in this case being entirely made up of the coarser tubes. At the same time it is not an uncommon occurrence to find small nodules entirely composed of the finer tubes without any traces of the coarser forms, and it is open to question whether the two sets of tubes necessarily belong to the same organism. This doubt seems to be strengthened by the occurrence, though rarely, of specimens of *Ortonella* in Westmorland with tufts of fine tubules associated with them, which are indistinguishable from the finer tubes in *M. gregaria*.

Other organisms to which *Ortonella* bears some resemblance are *Girvanella*, Nich., and *Sphærocodium*, Rothpl. It differs, however, from these genera in the radial arrangement of its tubes, which in *Girvanella* and *Sphærocodium* lie in concentric layers round the nucleus. Again, though Rothpletz has described dichotomous branching in *Girvanella*, this is certainly obscure in most British examples, including Nicholson's genotype from Girvan. It appears, however, from Dr. Rothpletz's description, to occur in *Sphærocodium Bornemanni*.

Systematic Position.—The genus *Ortonella*, as shown above, seems to be most nearly allied to *Mitcheldeania* and *Sphærocodium*, and, as both these forms appear referable to the calcareous algæ, *Ortonella* may also be provisionally placed among the Thallophyta. As regards its more definite systematic position, it seems to be most nearly related to the Siphoneæ, but, as Professor Seward cautiously remarks regarding *Girvanella*, *Siphonema*, and *Sphærocodium*, "It is wiser to regard such tubular structures as closely allied organisms, which are probably algæ, but too imperfectly known to be referred to any particular family."[1]

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[1] Rep. Brit. Assoc., Section C, 1913, and GEOL. MAG., Dec. V, Vol. X, pp. 440, 490, 545.

Aphralysia,[2] gen. nov. (Pl. XXI, Figs. 3, 4.)

The macroscopic characters of this organism can only be generally inferred, as specimens have not been isolated from the matrix. In translucent sections of the rock, however, these organisms are seen to occur as thick incrustations surrounding fragments of various organisms and, if isolated, they would appear as small nodules up to 10 mm. in diameter, having a slightly lobulate surface, thus resembling nodules of *Girvanella* or *Solenopora*.

Under the microscope the nodules are seen to be built up of a series of semicircular and semi-elliptical plates arranged in irregular alternating rows, having the convex surfaces of the plates directed uniformly outwards away from the centre of growth, giving a general appearance of wreaths of bubbles, encrusting fragments of shells, or the thalli of *Ortonella* and other algal forms. The growth usually starts with small plates resembling hollow blisters attached by their edges to the surface of the object which serves as a nucleus. The size of the blister-like cells increases in the succeeding row, and usually averages ·12 mm. in height in the centre. The length of the cells varies according to the position of the sections, but the height of the arch is remarkably uniform in the majority of cases, whatever the length of individual cell. These curved plates, bounding the outer surfaces of the cells, sometimes occur as very thin dark lines, but they are more frequently represented by a pale orange-coloured film or stain. This colouring matter may extend inwards so as to occupy a quarter or even a third of the cavity, the thickness depending apparently on the angle made by the wall with the plane of the section. There is a complete absence of circular sections, so that the cells cannot be tubular in character. The structure is thus shown to consist of a series of alternating rows of elongated, highly arched plates, each plate resting with its edges supported by the plates of the row below, exactly like a tangle of soap bubbles or a mass of foam.

No other definite structures can be made out, but occasionally in sections cut tangentially to the surfaces of the nodules a few curved plates may be observed (exactly similar in structure and colour to the boundary walls) which appear to divide up some of the more elongate cells. These may, however, be the edges of other cells cut by the plane of the section. This organism is frequently intergrown with layers of a flocculent deposit which may be classed under the general term '*Spongiostroma*'.

The exact nature of *Aphralysia* is somewhat doubtful. Its mode of growth and its intimate association with *Ortonella* and '*Spongiostroma*' would appear to suggest algal affinities, but the comparatively large size of its cells and their mode of growth differentiate it from any examples of fossil calcareous algæ known from the Lower Palæozoic rocks.

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[1] Seward, *Fossil Plants*, vol. i, p. 160, 1898.

[2] 'Chain of foam.' From ἄφρος, 'foam,' and ἅλυσις, 'a chain.'

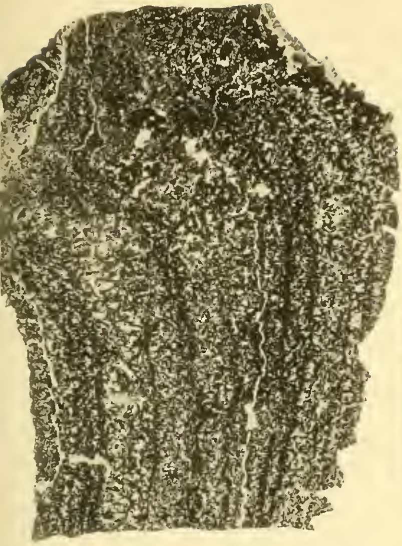

Fig. 1. Spongiostroma. × 2·5.

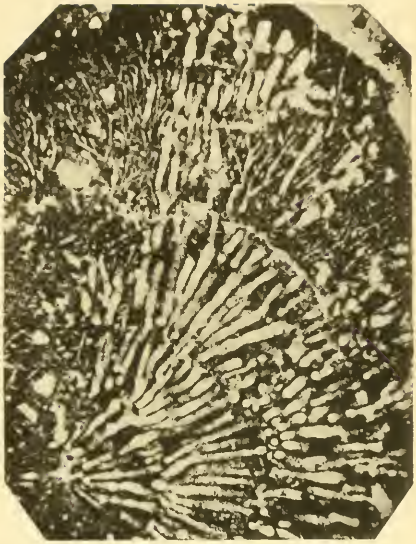

Fig. 2. Mitcheldeania. × 26.

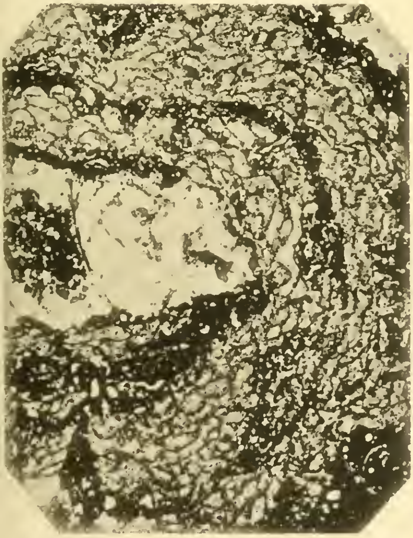

Fig. 3. Aphralysia. × 13.

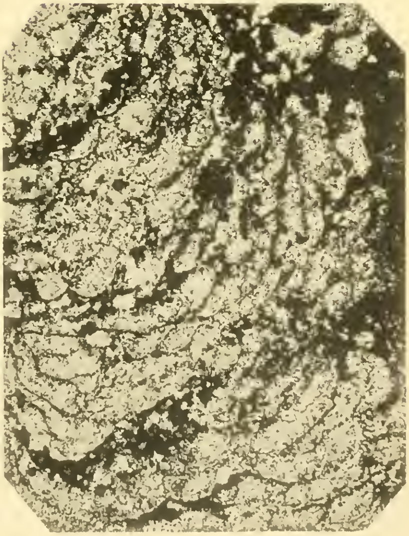

Fig. 4. Aphralysia. × 30.

E. J. Garwood, photo. *Bemrose & Sons Ltd., Collo.*

Though the material so far to hand does not afford sufficient evidence to warrant our assigning to it a definite systematic position, there can be no doubt as to its importance as a rock-forming organism.

Genotype.—Aphralysia carbonaria, sp. nov. (Pl. XXI, Figs. 3, 4.) The specimens so far met with appear to belong to only one species, for which on account of its widespread occurrence in the Lower Carboniferous rocks we suggest the specific name of '*carbonaria*'.

Horizons and Localities.—It occurs abundantly in the Lower Carboniferous rocks of the North-West of England at the base of the *Seminula gregaria* sub-zone. In the Shap and Ravenstonedale districts of Westmorland; also at the same horizon at Low Meathop in the Arnside district; more sparingly in the *Solenopora* sub-zone in Stone Gill, Ravenstonedale; in the upper *Dibunophyllum* sub-zone (*Girvanella* Nodular Band) at Humphrey Head in the Grange district; in association with *Mitcheldeania gregaria* in the Whitehead Limestone at Mitcheldean; at about the same horizon again in North Cumberland and near Tosson in Northumberland; also in the *Modiola* beds underlying the Bryozoa bed in the Avon Gorge, Clifton, exposed in the lower railway cutting near Cook's Folly.

'SPONGIOSTROMA.' (Pl. XXI, Fig. 1.)

In 1906 Gürich described and figured a number of somewhat obscure structures from the Dinantian rocks of the Namur district (under the generic names *Spongiostroma*, *Malacostroma*, etc.) which he regarded as encrusting Foraminifera.[1] More recently Professor Rothpletz has described two species of *Spongiostroma* (*S. balticum* and *S. Holmi*) from the Silurian rocks of Gotland.[2] Gürich's reference of these structures to the Protozoa appears to be decidedly speculative, while the features which he selects for the subdivision of the different forms into genera and species are very indefinite, and the detailed structure often varies greatly, even in the same specimen.

In the Lower Carboniferous rocks of Westmorland we meet with many similar structures which in places contribute largely to the formation of the deposit. They occur especially in the 'Algal Layer' at the base of the *Seminula gregaria* sub-zone, associated with *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4), and occasionally form undulating layers several inches in thickness. I have observed similar structures in the rocks of North Cumberland and West Northumberland and the Border country, also in the Forest of Dean, the Avon Gorge, and South Wales,[3] and it is probable that they will be found to be widely spread in shallow-water deposits of Dinantian age in Europe.

In transparent slices under low magnification they frequently show a general appearance of stratification lying roughly parallel to the bedding-planes (Pl. XXI, Fig. 1), while fine layers of a similar deposit are often seen under higher powers to be intergrown concentrically with specimens of *Ortonella* and *Aphralysia* (Pl. XXI, Figs. 3, 4). Under the microscope no definite cell-structure can be made out, and the general appearance is that of an indefinite flocculent precipitate of carbonate of lime which has the appearance of having been thrown down from solution as the result of the abstraction of $C\,O_2$ from water containing calcium bicarbonate in solution. The character of these structures, coupled with the general absence of definite mechanical and organic fragments, where they occur, points strongly to their organic origin, while their constant association with *Ortonella*, *Mitcheldeania*, and *Solenopora* would suggest that the conditions under which they were formed were of a lagoon character suitable for the growth of marine algæ. At the same time the absence of definite cell-structure suggests that they represent the insoluble $Ca\,C\,O_3$ precipitated in an amorphous condition as the result of absorption of $C\,O_2$ from the water by growing plants rather than definite structures built up in the cells of calcareous algæ.[1] General precipitation of this kind is well known to botanists at the present day. Thus the famous 'Sprudelstein' of Carlsbad has often been stated to have originated in this manner, though this has been disputed by some recent observers. There cannot, however, be any doubt regarding the action of certain plants in this connexion.

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[1] *Mém. du Mus. Roy. d'Hist. Nat. de Belgique*, t. iii.

[2] *Kungl. Svenska Vetenskap. Hand.*, Bd. xliii, No. 5, 1908.

[3] In specimens sent me by Mr. C. H. Cunnington.

During the progress of the bathymetrical survey of the Scottish lochs, abundant precipitation of calcium carbonate, due to plant action, was observed. In addition to lime-encrusted Characeæ in the lochs of Lismore, lime-encrustations were observed on the stones of the shore formed by minute lithophilous algæ, in the process of their metabolism, while certain plants such as *Myriophyllum spicatum* and *Potamogeton* were found to produce heavy precipitates of $Ca\,C\,O_3$. The former plant is stated by Mr. George West[2] to be so heavily coated with encrustations of carbonate of lime that the plants are often unable to rise to the surface for the purpose of pollenization. Were it not for the fact that the majority of the Scottish lochs lie in areas where the rocks are practically devoid of lime, this phenomenon would doubtless have been met with more frequently.

In the Swiss lakes also (Geneva, Neuchâtel, etc.) the blue-green algæ, according to Chodat, cause important precipitation of $Ca\,C\,O_3$. Indeed, in recent years there has been a growing conviction among writers on lake deposits (C. A. Davis,[3] Wesenburg-Lund,[4] Weltner,[5] Passarge,[6] and others) that the lime deposits in lakes are chiefly, if not entirely, due to organisms, among which plants often play a very important part. It seems highly probable, then, that similar amorphous deposits are also taking place in shallow seas, especially where lagoon conditions prevail and algæ flourish. Our knowledge of such deposits appears at present to be very scanty, and further investigation is greatly needed.

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[1] Thus, if water is saturated with calcium bicarbonate, then for each gram of $C\,O_2$ abstracted by plants, 2·3 grams of $Ca\,C\,O_3$ are precipitated.

[2] *Bathymetrical Survey of the Fresh-water Lochs of Scotland*, vol. i, p. 213, 1910.

[3] *Journal of Geology*, Chicago, vol. viii, p. 485; vol. ix, p. 491.

[4] *Meddel fra Dansk Geolog. Foren. Kobenhavn*, vii, 1.

[5] *Archiv f. Naturges.*, vol. lxxi, p. 277.

[6] *Jahrb. d. Königl. Preuss. Geol. Landesanst*, vol. xxii, p. 79.

EXPLANATION OF PLATES XX AND XXI.

Plate XX.

Fig. 1. *Ortonella furcata*, gen. et sp. nov. Section through a typical nodule. Natural size. Base of the *Seminula gregaria* sub-zone, Ravenstonedale, Westmorland.

,, 2. *O. furcata*. Thin section through above. × 20.

,, 3, 4. *O. furcata*, showing dichotomous branching of tubes. × 55.

Plate XXI.

Fig. 1. *Spongiostroma* cf. *Malacostroma concentricum*, Gürich. × 2·5. Base of the *Seminula gregaria* sub-zone, Fawcett Mill, near Orton, Westmorland.

,, 2. *Mitcheldeania gregaria*, Nich. × 26. Showing coarse and fine tubes. Zone of C_1–C_2 of Dr. Vaughan's classification. Scully Grove, Mitcheldean.

,, 3. *Aphralysia carbonaria*, gen. et sp. nov. × 13. Intergrown with layers of a flocculent deposit—'*Spongiostroma*.'

,, 4. *A. carbonaria*, gen. et sp. nov. × 30. From the 'Algal Band' associated with *Ortonella*. Base of *Seminula gregaria* sub-zone, Wath, near Orton, Westmorland.

IV.—Gypsum and Anhydrite in Genetic Relationship.

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Professor of Geology and Mineralogy, University of Manitoba.

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In certain geological horizons where there is evidence of continuous deposition of salts from the waters of inland basins, gypsum and anhydrite are found closely associated, while in other similar horizons gypsum may occur with apparently no trace of anhydrite. Some Upper Silurian occurrences in North America, the Lower Carboniferous of Eastern Canada, and the Zechstein of Northern Germany are illustrative of the association of both minerals, while in more recent gypsum horizons anhydrite seems to appear less frequently. Even in the one horizon anhydrite is found to be of only local occurrence. In New York and in Michigan the Salina formation contains both gypsum and salt deposits, but practically no anhydrite. In Manitoba, on the other hand, in an Upper Silurian formation which cannot be definitely correlated with the Salina of New York, but which is at any rate of approximately the same age, gypsum and anhydrite occur in the most intimate relationship.

The conditions of stability of gypsum and of anhydrite, whether in presence of water or of salt solutions, were investigated by van't Hoff and his co-workers by vapour-tension methods. The relationship of both forms to the half-hydrate ($CaSO \cdot \frac{1}{2}H_2O$), which is obtained by ordinary calcination processes, and to 'soluble anhydrite', which is formed when precipitated gypsum is maintained at temperatures